



Case Report

Paradoxical air embolism through patent foramen ovale during consensual intercourse in a non-pregnant young female

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ABSTRACT

Sudden vaginal bleeding and a cardiac arrest occurred in a 18-year-old female during consensual intercourse. Resuscitation procedures, applied at the arrival of a medical emergency team, restored the cardiac function allowing admission to hospital, where two vaginal mucosal lacerations were diagnosed and sutured. Cardiological investigations diagnosed a left ventricle myocardial infarction and a patent foramen ovale while a brain CT scan showed ischemic signs and intravascular air images. Death occurred after 48 h, due to heart failure, cerebral anoxia and multiorgan failure. Autopsy confirmed a patent foramen ovale considered as responsible for a paradoxical air embolism. Judicial Authority evaluated the fatal paradoxical air embolism as a consequence of an unpredictable accident occurred during consensual intercourse without sexual violence.

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1. Introduction

Air venous embolism has been reported after consensual sexual activity or autoerotic practice in cases of non-pregnant or pregnant women, when air passing through vaginal lacerations entered the venous circulation and the pulmonary arteries, causing gas exchange impairment, right ventricular strain, cardiac arrhythmias, cardiac failure, brain and cardiac ischemia and possible death.^{1–5}

Paradoxical air embolism, which is an uncommon variant of air arterial embolism, occurs in subjects after medical procedures, aviation altitude exposition and diving sports, when air entering the venous circulation crosses a patent foramen ovale and involves the left cardiac chambers and the coronary and brain vessels.^{6–21}

We report a case of death due to paradoxical air embolism during consensual intercourse in a non-pregnant woman and examine pathophysiological and medico-legal implications.

2. Case report

An 18-year-old female engaged in sexual intercourse with her new male partner. It was not the first sexual intercourse in the life of the young female, but it was her first sexual intercourse with that new male partner. Penile penetration of the vagina was reported without digital foreplay, being both partners kneeling on the bed, so that the female's pelvic region was elevated over the

thorax and the right heart level. After some minutes of intercourse the female sighed, became comatose while serious vaginal bleeding and a cardiac arrest occurred.

Upon the arrival of a medical emergency team, cardiac arrest was diagnosed as due to an hemorrhagic shock for serious bleeding from the genital region, hence resuscitation attempts started promptly with tracheal intubation, external cardiac massage, electric defibrillation and intravenous inotropic drugs therapy.

The cardiac function was restored and the patient was admitted to hospital. At the ICU arrival, two mucosal and wall lacerations were diagnosed at the posterior surface of the vaginal cavity (3.5 cm and 1.5 cm length). Blood transfusion therapy was applied while the patient underwent an emergency surgical operation to suture the vaginal mucosal lacerations. At the end of the surgical operation the patient returned to ICU for the treatment of a postanoxic coma.

Neurophysiological testing (electroencephalography and somatosensory-evoked potentials) confirmed a serious cortex and brain postanoxic impairment, while CT scan images showed brain oedema and ischemic hypodensity signs at the thalamus, brainstem and cerebellum. Significant intravascular air amounts were found at the subcortical frontal and occipital brain regions and at the right subcortical cerebellum regions also (Fig. 1). No blood and urine levels of opioids, benzodiazepines, barbiturates, amphetamines and alcohol were found by toxicological tests.

Transesophageal echocardiographic examination showed the presence of a patent foramen ovale (an injection test of a small amount of mixed water and air through a central venous catheter confirmed the passage of air bubbles from right to left atrium) and dyssynergic areas at the apex of the left ventricle.

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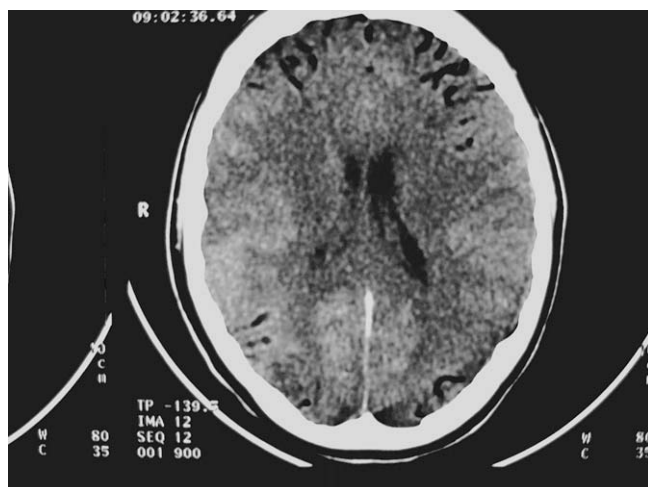


Fig. 1. CT scan images, intravascular air found at the subcortical frontal and occipital brain regions.

Hemodynamic and renal functions worsened and a cardiogenic shock and renal failure occurred. Death occurred 48 h later due to multiorgan failure.

Under Police investigations the male partner confirmed that some minutes after beginning the consensual intercourse, the female, who was kneeling on the bed, gasped, falling comatose and suffering vaginal bleeding and a cardiac arrest. The male called for medical emergency rescue and tried to resuscitate the female who was unresponsive. The male denied the use of drugs or violent non consensual intercourse, he was examined by forensic doctors but no genital or other injuries were found on his body, while no drugs were found in his blood and urine samples. Police examined the bedroom and the house, but no signs of violence or blood were found.

At autopsy no external signs of violence were found on the woman's body apart from holes at hands and neck due to peripheral and central venous cannulation. No lesions were found at the external vaginal region.

Two lacerations were found at the posterior region of the vaginal cavity: (1) one rectilinear laceration was from the hymenal border to the cervix, 3.5 cm length, depth to the muscular layer of the vaginal wall, with irregular and frayed margins, and surgically sutured; (2) one rectilinear laceration was from the hymenal border and parallel with the first laceration, 1.5 cm length, depth to the muscular layer of the vaginal wall, with irregular and frayed margins, and surgically sutured.

The anatomical section of the posterior vaginal wall showed, in the depth of the mucosal lacerations, blood infiltration of mucosa and muscular layer. Both lacerations involved the mucosal and muscular layers but didn't reach the tunica adventitia. The microscope examination of the mucosa of the uterus showed typical late secretory (premenstrual) endometrium aspects.

External examination of anal districts showed mucosal micro-abrasions without ecchymosis, while no lesions were found at the anal wall or rectum districts.

External thorax examination showed a pectus excavatum morphology.

After the pericardial sac was opened, 50 ml of serous liquid were found, and the heart presented regular weight, volumes, diameters and thickness of all chambers and regular valvular areas, while a patent foramen ovale was found at the interatrial septum.

Although all coronary vessels presented a regular lumen without pathological occlusions, a large transmural myocardial infarctual area was found at the posterior wall of the left ventricle,

near the apex, which was well confirmed by microscope evaluation of tissue sections (myocardial fibres blurring and contraction bands, coagulative necrosis and polymorphonuclear leucocyte infiltrates) (Fig. 2).

The brain presented regular weight, volumes and morphology but diffuse signs of oedema and ischemic lesions at the frontal and occipital cortex, thalamus, brainstem and cerebellum.

Lungs presented moderate tissue congestion and oedema considered as early ARDS signs and a moderate amount of serous liquid was found at both pleural cavities.

Abdominal examination did not find signs of bleeding or other lesions involving abdominal organs.

The autopsy finding of a patent foramen ovale at the interatrial septum suggested the pathophysiological steps of the young woman's sudden death.

Vaginal mucosal and wall lacerations were considered as points of entrance of the air from the vaginal cavity involving the perivaginal and pelvic venous districts, the inferior cava vein, the right atrium, the patent foramen ovale, the left heart chambers, and finally the coronaric and brain vessels.

Judicial Authority evaluated the death as the consequence of a paradoxical air embolism during the consensual intercourse.

No responsibilities involving the male partner were considered because the lesions of the vaginal mucosa and the paradoxical air embolism were an unfortunate accident during the consensual intercourse and occurred without sexual violence.

3. Discussion

Venous and arterial embolism are two broad categories of cardiovascular events, with different ways of entry and sites where the emboli lodge.

Venous embolism occurs when air enters the systemic venous system and the pulmonary circulation, frequently as a consequence of medical or surgical procedures or peripheral traumas, causing interference with pulmonary gas exchange and right heart failure. Physical preconditions for the entry of air to the breached venous vessels, are the presence of open lumen non-collapsed veins and the presence of intravenous subatmospheric pressure.^{6,7}

Cases of death due to venous air embolism after consensual sexual activity, in non-pregnant or pregnant women (before or after delivery or after abortion), have been reported in literature, occurring when an important amount of air enters the systemic venous system through vaginal mucosa lesions and is transported to the

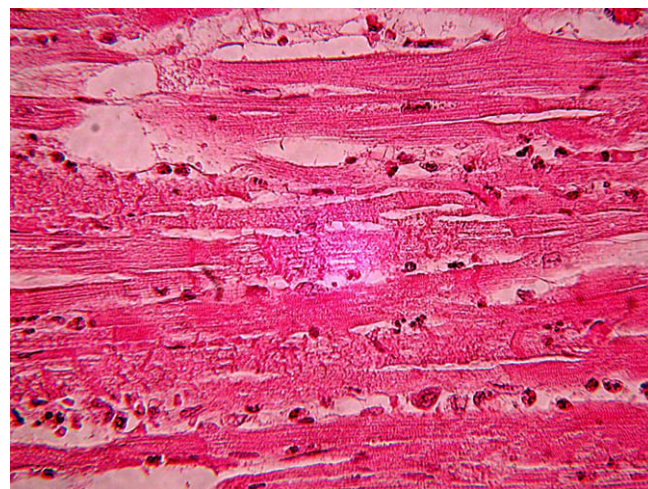


Fig. 2. Myocardial microscope section: myocardial fibres blurring and contraction bands, coagulative necrosis and polymorphonuclear leucocyte infiltrates.

right atrium and ventricle, involving pulmonary gas exchange and circulation and causing acute right heart failure, cerebral and cardiac ischemia.⁸

The passage of air to the right heart may be facilitated by: (1) a piston-like effect during the penile penetration of the vagina, causing significant mucosal and wall injuries and increasing the quantity of air introduced into endometrial veins which are engorged by sexual arousal; (2) a kneeling position on the bed, so that the pelvic region is elevated over the thorax and the right heart level, generating a subatmospheric favourable pressure gradient for the passage of air to peripheral venous vessels; (3) an increase of respiratory ventilation during the consensual intercourse, accentuating the negative intrathoracic pressure during inspiration and causing an important drawing of venous bubbles to the right atrium.

All the above conditions occurred during the consensual intercourse in the case we report, while some predisposing factors to vaginal wall lesions reported by Schulz and Tsokos, as young age, first sexual intercourse with a new male partner (but not the first sexual intercourse in the life of the female partner), posterior penile penetration (called “a tergo” position) and pre-menstrual period, were present too.⁹

Schulz and Tsokos reported that the penile size is not sufficient alone to cause vaginal lesions while the ratio between the penile and the vaginal size is a real risk factor for vaginal lesions.⁹

The penile size of the male partner and the vaginal size of the female partner (under medical and necroscopic inspections) were found as normal so that the ratio between their penile and vaginal size was not considered a significant risk factor for vaginal lesions.⁹

In the case we report the posterior location and the linear morphology of the vaginal wall lacerations were similar to those described by Schulz and Tsokos, due to increased tension and shortening of vaginal wall tissues, when a deep and powerful posterior penile penetration is applied.⁹

Arterial air embolism occurs when air enters directly into arteries of systemic circulation as during extracorporeal circulation, or into the pulmonary veins as during pulmonary barotrauma with overexpansion and decompression of lungs.^{6,7}

Paradoxical air embolism, which is a variant of arterial embolism, occurs when air bubbles shunt from the venous side to the arterial side of circulation in the presence of any right to left shunt, including a patent foramen ovale, which is present from birth in several subjects (the presence ranges between 15% and 40% in various studies).^{10–14}

A shunt due to a patent foramen ovale develops a fast involvement of the left atrium and ventricle, causing coronary and cerebral artery obstructions with heart and brain ischemic and infarctual lesions.^{12–14}

Toung et al. reported that air volumes of 200–300 ml are lethal for adult subjects with foramen ovale closed with a flap-like septum primum, causing death due to venous air embolism.¹³

No data are available from literature about the amount of air volumes lethal for adult subjects with patent foramen ovale. Muth and Shank underline that arterial vessels of skeletal muscles or viscera well tolerate small air emboli, while embolization of coronary and cerebral circulation with small amounts of air bubbles coming from the right atrium through a patent foramen ovale, results in severe morbidity or death due to myocardial ischemia or infarction.⁶

Some specific pathophysiologic steps of paradoxical air embolism are reported in literature to explain the right-to-left transcatheter shunting mechanism of bubbles in presence of a patent foramen ovale. During normal haemodynamic conditions, in presence of a patent foramen ovale, a left to right shunt is not present, while a transient reversal of the left-to-right atrial differential pressure may occur during early diastole and isovolumetric con-

traction of the right ventricle. A reversal gradient may occur and increase under other transient physiologic events which increase the right atrial pressure as cough, inspiration, Valsalva maneuver, posture, high pulmonary vascular resistances (due to hypoxemia, obstructive sleep apnea, positive pressure mechanical ventilation).^{7,9}

In the case we report some of these events occurred, as the male kneeling on the bed with the pelvic region elevated over the thorax and the right heart level, the increase of depth and frequency of respiratory ventilation. These events could have increased the right atrial pressure, causing the shunt of air bubbles from the right atrium to the left atrium and ventricle, and finally the death of the subject.^{7,9}

The uncommon association of patent foramen ovale and pectus excavatum, described by De Leon et al., was also present in the case we report.¹⁵

Cases of paradoxical air embolism have been reported in subjects with patent foramen ovale, during aviation altitude exposition, diving sports and several medical procedures as cesarean delivery, neurosurgery in sitting position, scoliosis surgery, transplantation or resection liver surgery, central venous catheters management, but no data are available on cases of paradoxical air embolism during consensual sexual activity.^{16–21}

In conclusion, we observe that:

- (1) The case we report appears to be the first event of fatal paradoxical air embolism during a sexual consensual intercourse in a non-pregnant female, with traumatic lacerations of the vaginal mucosa and wall, while a piston-like effect rapidly introduced a significant and pressured volume of air inside the vaginal cavity and the lumen of the local veins. A gradient of venous pressure by the elevation of the vagina above the heart level during the kneeling position of the female, as well as an increase of respiratory ventilation, could have favoured the passage of air to the venous circulation and right atrium, the shunting of the patent foramen ovale, and finally cardiac and brain ischemic lesions.
- (2) Autopsy findings, in women dead for a cardiac arrest during sexual intercourse, may support the forensic diagnosis discovering a patent foramen ovale responsible for a paradoxical air embolism and confirm pre-mortem clinical data.

Conflict of interest

None declared.

Funding

None declared.

Ethical approval

None declared.

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